

REMARKS

With careful attention to the Examiner's comments in the Office Action, the Application has been amended to place it in condition for allowance. The remarks presented herein are believed to be fully responsive to the Office Action.

Claims 9-17 are pending in the present application. Claim 9 has been currently amended and claims 10 and 17 have been canceled. The independent claim recited by the present application is claim 9. No new matter is added.

DUTY TO DISCLOSE INFORMATION MATERIAL TO PATENTABILITY:

The Examiner advised Applicant of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the Examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a). Applicant hereby states that claims 9-17 were jointly invented by all the inventors listed in the present application.

CLAIM REJECTIONS:

The Office Action states that claims 9-17 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kuo et al. (U.S. Patent No. 6,515,306) (“Kuo et al.”), Ye et al. (U.S. Pat. No. 6,479,313) (“Ye et al.”) and Hashimoto (U.S. Pat. No. 6,508,879) (“Hashimoto”).

Applicants respectfully traverse these rejections because the Examiner's characterization of Ye et al. and Hashimoto is incorrect. Kuo et al. fails to disclose the limitations recited in the independent claim 9 of the present application and Ye et al. and Hashimoto still fails to remedy

the deficiencies of Kuo et al. in reaching all the elements and limitations of the claims of the present invention. Neither Kuo et al. nor Ye et al. nor Hashimoto nor combination thereof disclose or teach all the elements and limitations of the claims of the present invention.

Claim 9

The Office Action admits that "Kuo et al. do not explicitly show forming said p-type GaN layer using ammonia and hydrazine-based material as nitrogen precursor and without a subsequent annealing process and the particular flow rates claimed." However, the Office Action states that "Ye et al. teach (e.g. Column 5 Lines 14 to 23) to form a p-type GaN layer using ammonia as nitrogen precursor and without a subsequent annealing process and N₂ and H₂ as carrier gases to form low-resistance p-type semiconductor layers (Column 2 Lines 8 to 13)."

Before Applicant shows the difference between the cited prior art and the claimed invention, we respectfully present mechanism of passivation and activation of Mg-H complex when ammonia (NH₃) and Magnesium (Mg) dopant are used for growing a p-type III-nitride semiconductor as follows: During growth of p-type III-nitride semiconductor, the hydrogen (H) from the ammonia and Magnesium (Mg) are combined into the Mg-H complex so that it prevents the Magnesium (Mg) from functioning as p-type dopant. In an effort to overcome such shortcomings in conventional art, a few processes have been suggested. One of the suggested processes is thermal heating for breaking the Mg-H complex, which has been often used in the relevant industry. The other suggested process uses irradiation of laser beam for breaking the Mg-H complex, which has common features with the thermal heating process in light of supplying energy for breaking the Mg-H complex. As such, the prior art requires a process for breaking the Mg-H bond (complex).

On the other hand, the present invention discloses that, without using hydrogen (H) during the growth of p-type III-nitride semiconductor, nitrogen (N₂) is used as carrier gas and Hydrazine is used as an N precursor so that post-activation is not required because Mg-H complex does not occur.

Whereas, as the present application explains the conventional technology in the above quoted specification, Ye et al. uses an irradiation method for breaking the Mg-H complex as recited below in Column 5 Lines 14 to 23:

During the growth process, NH₃ is decomposed to generate hydrogen atoms. These hydrogen atoms react with the p-type dopant, such as Mg, and form Mg--H bonds or Mg--H complexes. Thus, GaN into which p-type impurity is doped is highly resistive or semi-insulating. Irradiating the p-doped semiconductor compound with high-energy x-ray photons, however, breaks the Mg--H bonds and releases the hydrogen from the Mg--H bond to leave a characteristic p-type GaN layer. The p-type impurity, Mg, then behaves as an active acceptor.

Unlike the Examiner's position, Ye et al. does not teach or suggest the claimed invention, particularly the limitation of "forming the p-type nitride semiconductor layer of the plurality of nitride semiconductor layers, without a subsequent annealing process, by using ammonia and hydrazine-based material as nitrogen precursor wherein the p-type nitride semiconductor layer contains gallium, and the molar flow ratio of hydrazine-based material/gallium is 1 to 10 and, upon thermal decomposition, the hydrazine-based material generates a radical that is combined with a hydrogen radical to eliminate the hydrogen radical to make the p-type nitride semiconductor layer without the subsequent annealing process during the formation of the p-type nitride semiconductor layer." In the claimed invention, the hydrazine-based material as nitrogen precursor together with ammonia generates a radical upon thermal decomposition and the radical is combined with a hydrogen radical to eliminate the hydrogen radical. The claimed invention discloses a method of forming a p-type nitride semiconductor layer without additional annealing,

which means removing Mg-H complex by thermal treatment. Mg-H complex results from the combination of Mg from p-type dopant with H from NH₃(ammonia). The claimed invention reduces generation of Mg-H complex by capturing H from ammonia through radicals from hydrazine-based source. Unlike the claimed invention, Ye et al. does not use both the hydrazine-based material and ammonia as nitrogen precursor. Thus, the method of Ye et al. should supply energy for breaking the Mg-H complex, such as irradiating the p-doped semiconductor compound with high-energy x-ray photons to break the Mg--H bonds.

The Office Action further states that "Hashimoto teaches (e.g. Column 5 Line 59 to Column 6 Line 51) to use a hydrazine-based material with CH₃ or NH₃ and ammonia as a nitrogen precursor to improve the crystallinity of the semiconductor layers (Column 2 Lines 12 to 19)." Column 6 Lines 18 to 51 recites as follows:

The decomposition efficiency of the aforementioned nitrogen-including compound is higher than that of ammonia. For example, when the group III-V compound semiconductor including only nitrogen as the group V element is subject to growth, the following is observed. Using ammonia as a nitrogen source, a mole ratio (a supply ratio) of ammonia to the organic metal as a source of the group V element is ammonia/organic metal=approximately 10,000. On the other hand, using the aforementioned nitrogen including compound as a nitrogen source, the group III-V nitride compound semiconductor can be grown despite the small supplied amount of the nitrogen-including compound, which is a nitrogen including compound/organic metal=approximately 50, at the same growth temperature (the temperature of the substrate 14 inside of the reaction tube 3, that is, the temperature of substrate 21) as the growth temperature using ammonia as a nitrogen source. Specifically, the difference in the amounts supplied becomes larger as the growth temperature decreases. Accordingly, the use of the aforementioned nitrogen-including compound enables nitrogen contributing growth to increase at a low temperature; thereby, a large amount of nitrogen is supplied onto the growth surface of the substrate 21. As a result, the lack of nitrogen in the grown group III-V nitride compound semiconductor is improved and a group III-V nitride compound semiconductor with enhanced crystallinity is obtained.

Unlike the Examiner's position and the claimed invention, Hashimoto does not teach or suggest use of **both the hydrazine-based material and ammonia as a nitrogen precursor.** Hashimoto teaches use of **either the hydrazine-based material OR ammonia as a nitrogen precursor, depending on the temperature.** Since the decomposition efficiency of the nitrogen-including compound is higher than that of ammonia at a low temperature, Hashimoto teaches **use of the nitrogen-including compound as a nitrogen precursor, instead of ammonia.** As disclosed in the present application, if the combination of hydrazine and ammonia is used as a nitrogen precursor, hydrogen radicals existing in a gas phase layer from ammonia would be removed effectively by means of NH₂ and CH₃ radicals of hydrazine so as to minimize formation of the Mg--H complex, which is not taught in Hashimoto. (*See para. [0036] of the present application*). Further, the growth in Hashimoto needs a post-activation because it does not use both the hydrazine-based material and ammonia as a nitrogen precursor. (i.e., *see Column 8 Lines 48 to 52*).

After growing layers from the n-side contact layer 31 to the p-side contact layer 37, heat treatment is performed thereon in order to activate the p-type impurities that have been doped in the p-type guide layer 35, the p-type cladding layer 36, and p-side contact layer 37.

Since Kuo et al., Ye et al. and Hashimoto all have Mg-H complex problem, they should solve this problem by using post-activation such as thermal heating or irradiation of X-rays. Whereas, the claimed limitation of "without a subsequent annealing process" along with the amended limitation of making p-type layer with eliminating the hydrogen (H) from ammonia by radicals makes it clear that post-activation such as thermal heating or irradiation is not required for making a p-type layer in the claimed invention.

Since all of Kuo et al., Ye et al. and Hashimoto use the post-activation to solve the Mg-H complex problem, there are no teachings, motivations and/or suggestions to combine those references. As such, neither Kuo et al. nor Ye et al. nor Hashimoto nor combination thereof teaches or suggests the limitations of "forming the p-type nitride semiconductor layer of the plurality of nitride semiconductor layers, without a subsequent annealing process, by using ammonia and hydrazine-based material as nitrogen precursor wherein the p-type nitride semiconductor layer contains gallium, and the molar flow ratio of hydrazine-based material/gallium in 1 to 10 and, upon thermal decomposition, the hydrazine-based material generates a radical that is combined with a hydrogen radical to eliminate the hydrogen radical to make the p-type nitride semiconductor layer without the subsequent annealing process during the formation of the p-type nitride semiconductor layer." Therefore, claim 9 of the present invention is in condition for allowance.

The amended limitations of "wherein the p-type nitride semiconductor layer contains gallium, and the molar flow ratio of hydrazine-based material/gallium in 1 to 10 and, upon thermal decomposition, the hydrazine-based material generates a radical that is combined with a hydrogen radical to eliminate the hydrogen radical to make the p-type nitride semiconductor layer without the subsequent annealing process during the formation of the p-type nitride semiconductor layer" is supported by the original specification, for example, paras. [0036]-[0038] of the present application. No new matter is added.

Claims 10-17 depend from independent claim 9 and, as such, are in allowable condition since claim 9 is clearly allowable over the cited prior art.

In light of the aforementioned amendments and discussion, Applicant respectfully submits that the application is now in condition for allowance.

Application of: Tae-Kyung Yoo
Serial No.: 10/563,269
Amendment B

If any issue regarding the allowability of any of the pending claims in the present application could be readily resolved, or if other action could be taken to further advance this application such as an Examiner's amendment, or if the Examiner should have any questions regarding the present amendment, it is respectfully requested that the Examiner please telephone Applicant's undersigned attorney in this regard.

Respectfully submitted,

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